Chapter 12

Leg: Femur, Patella, Tibia, and Fibula

The evolution of the tetrapod leg from pelvic fin structures mirrors that of the arm as described in Chapter 9. As with the arm, there is a single proximal limb element and two distal limb elements. The single thigh bone, the **femur**, is the serial homolog of the upper arm bone, the humerus. Likewise, the lower bones of the leg, the **tibia** and **fibula**, are serial homologs of the radius and ulna. The general structural layout of leg elements differs from that of the arm in one notable way: the largest sesamoid bone in the body, the **patella**, lies at the knee joint. The patella is functionally analogous to, if not a serial homolog of, the olecranon (now fused to the ulna, but in some earlier tetrapods it was a separate bone, the ulnar sesamoid). The bipedal mode of locomotion practiced by hominids has resulted in major specializations of the leg bones.

12.1 Femur (Figures 12.1–12.8)

12.1.1 Anatomy

The femur is the longest, heaviest, and strongest bone in the body. It supports all of the body's weight during standing, walking, and running. Because of its strength and density, it is frequently recovered in forensic, archaeological, and paleontological contexts. The femur is a particularly valuable bone because of the information it can provide on the stature of an individual (Chapter 19).

The femur articulates with the acetabulum of the os coxae. Distally, it articulates with the patella and the proximal tibia. The leg's actions at the hip include medial and lateral rotation, abduction, adduction, flexion, and extension. At the knee, motion is far more restricted, confined mostly to flexion and extension. Although the main knee action is that of a sliding hinge, this joint is one of the most complex in the body.

a. The **femoral head** is the rounded proximal part of the bone that fits into the acetabulum. It constitutes more of a sphere than the hemispherical humeral head.
b. The **fovea capitis** is the small, nonarticular depression near the center of the head of the femur. It receives the *ligamentum teres* from the acetabular notch of the os coxae.
c. The **femoral neck** connects the femoral head with the shaft and the greater trochanter.
d. The **greater trochanter** is the large, blunt, nonarticular prominence on the lateral, proximal part of the femur. It is the insertion site for the *gluteus minimus* (anterior aspect of the trochanter) and *gluteus medius muscles* (posterior aspect), both major abductors of the thigh

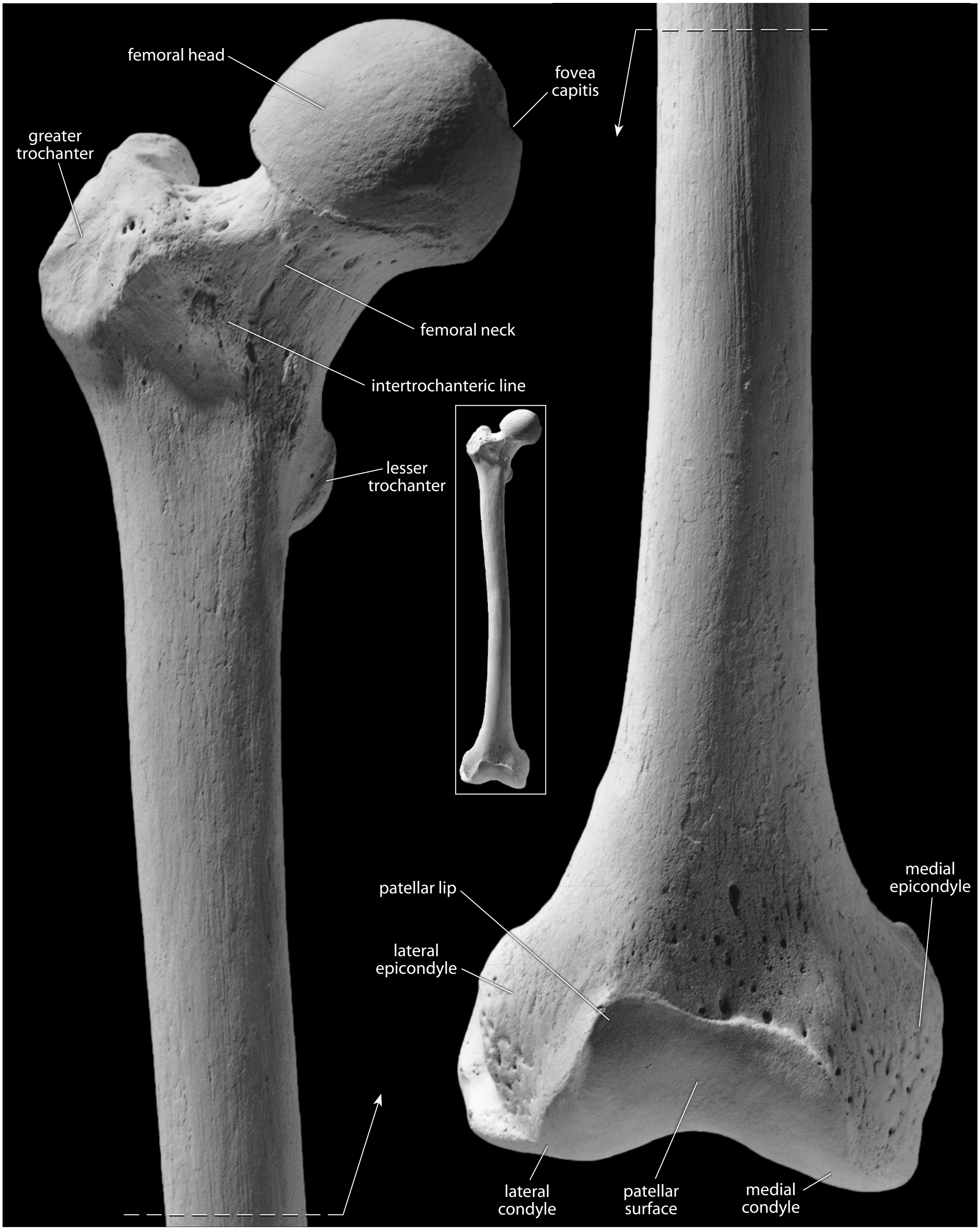

Figure 12.1 **Right femur, anterior.** *Left:* proximal end; *right:* distal end. Natural size.

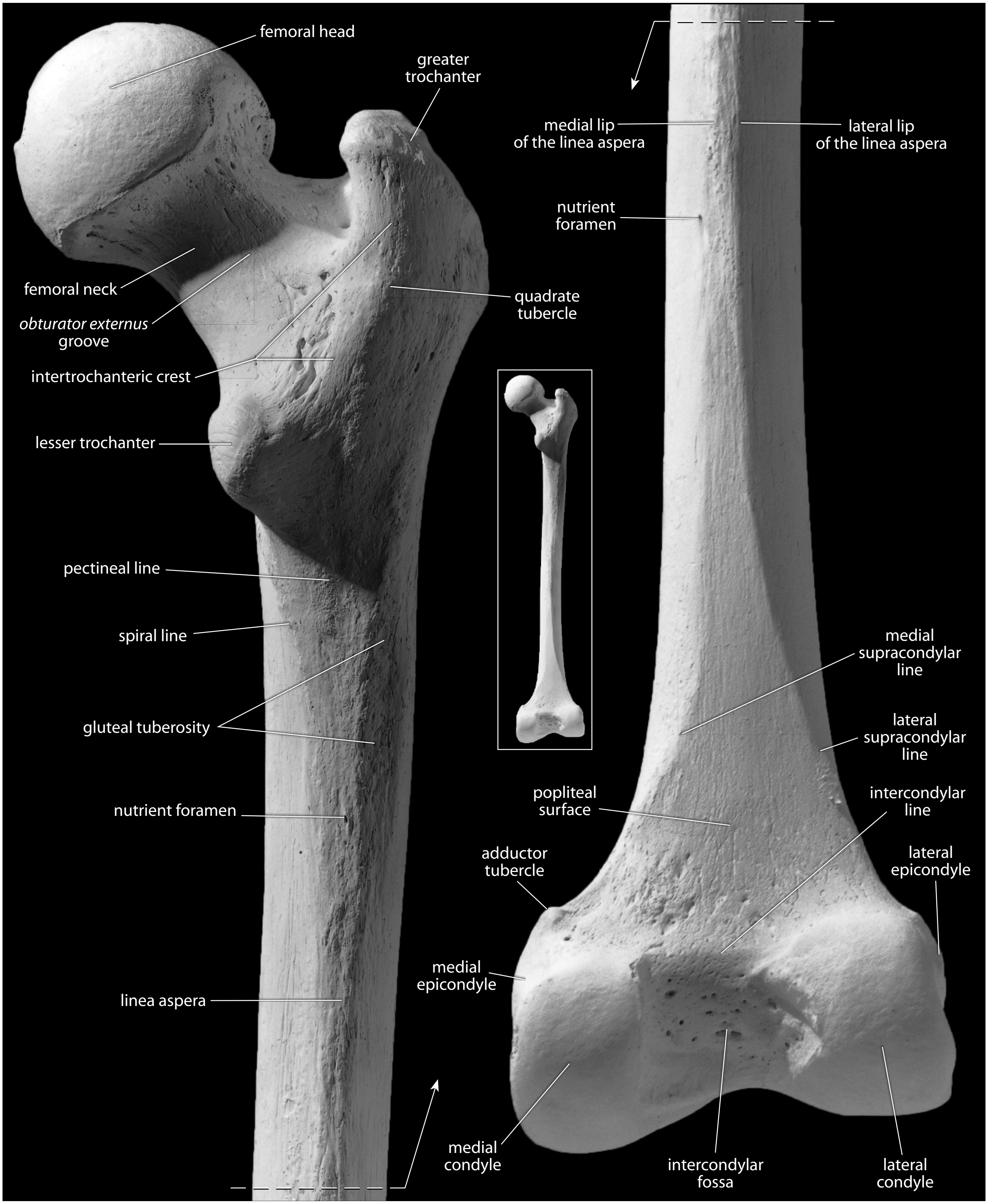

Figure 12.2 **Right femur, posterior.** *Left:* proximal end; *right:* distal end. Natural size.

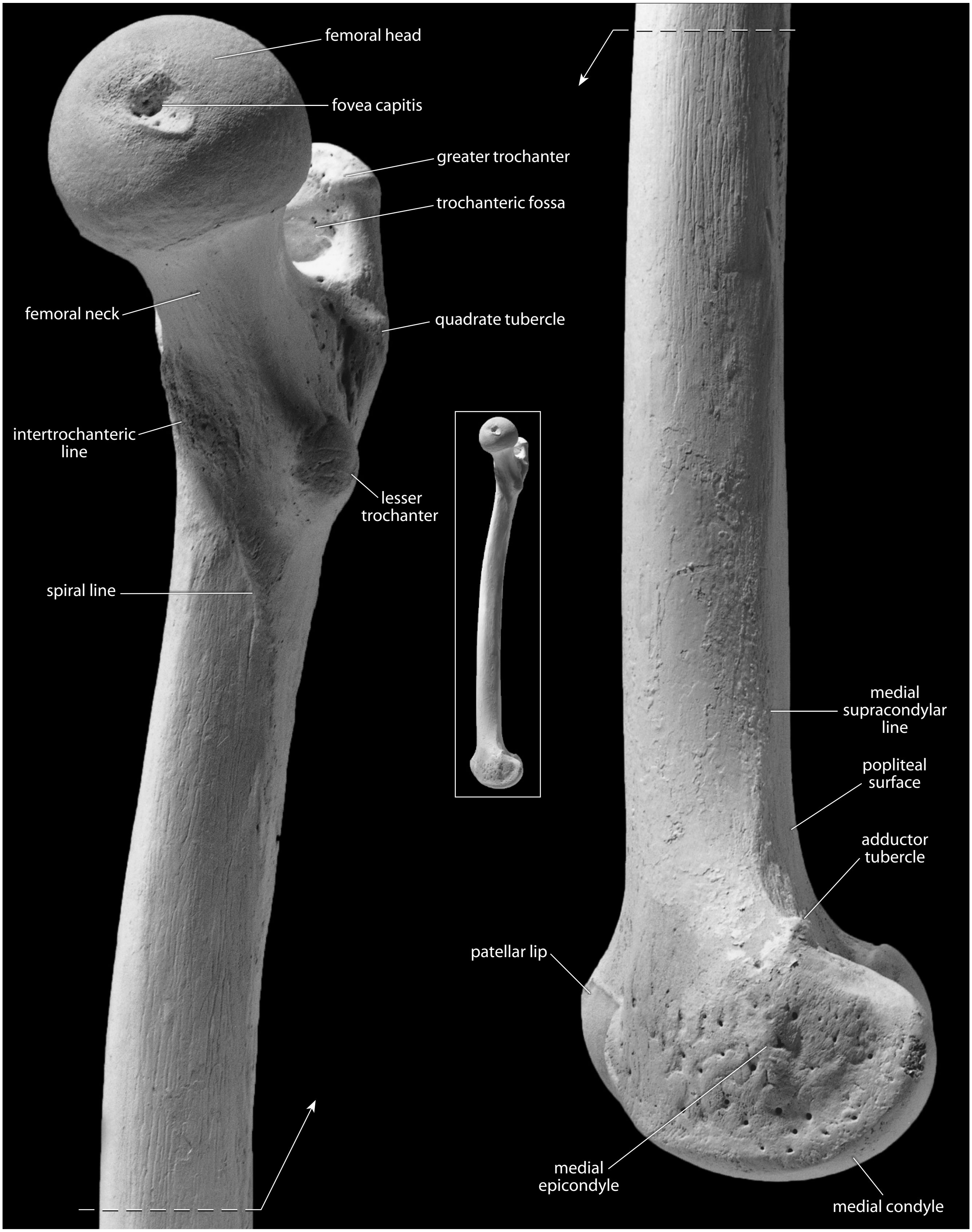

Figure 12.3 **Right femur, medial.** *Left:* proximal end; *right:* distal end. Natural size.

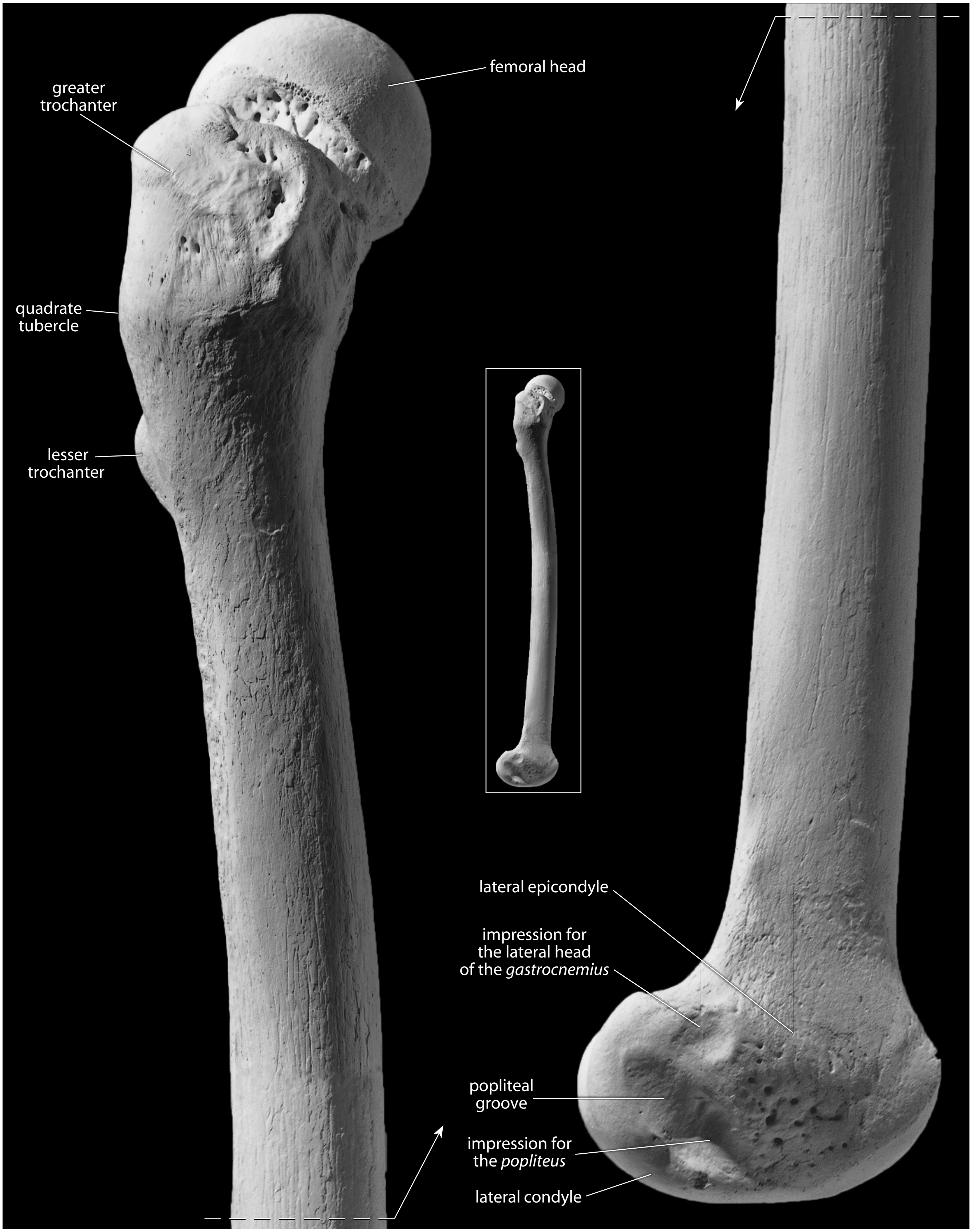

Figure 12.4 **Right femur, lateral.** *Left:* proximal end; *right:* distal end. Natural size.

and stabilizers of the hip. Their origins are on the broad, flaring iliac blade of the os coxae. These muscles are crucial in stabilizing the trunk when one leg is lifted from the ground during bipedal locomotion.

e. The **intertrochanteric line** is a variable, fairly vertical, roughened line that passes between the lesser and greater trochanters on the anterior surface of the base of the neck of the femur. Superiorly, this line anchors the *iliofemoral ligament*, which is the largest ligament in the human frame. It acts to strengthen the *joint capsule* of the hip.

f. The **trochanteric fossa** is the pit excavated into the posteromedial wall of the greater trochanter. This pit is for insertion of the *tendon of obturator externus*, a muscle that originates around and across the membrane that stretches across the obturator foramen of the os coxae. This muscle acts to rotate the thigh laterally at the hip. Just above its insertion, the medial tip of the greater trochanter receives several hip muscles: the *superior* and *inferior gemelli*, the *obturator internus*, and the *piriformis*. The latter two are important abductors, and all of these muscles can rotate the femur laterally.

g. The **obturator externus groove** is a shallow depression aligned laterally and superiorly across the posterior surface of the femoral neck. In hominids, erect posture brings the *tendon of the obturator externus muscle* into contact with the posterior surface of the femoral neck, creating the groove.

h. The **lesser trochanter** is the blunt, prominent tubercle on the posterior femoral surface just inferior to the point where the neck joins the shaft. This is the point of insertion of the *iliopsoas tendon* (the common *tendon of the iliacus muscle*, originating in the iliac fossa, and the *psoas major muscle*, originating from the lumbar vertebrae and their disks). These muscles are major flexors of the thigh at the hip.

i. The **intertrochanteric crest** is the elevated line on the posterior surface of the proximal femur between the greater and lesser trochanters. It passes from superolateral to inferomedial. Just above its midpoint is a small tubercle (the **quadrate tubercle**), which is the site of insertion of the *quadratus femoris muscle*, a lateral rotator of the femur.

j. The **gluteal tuberosity** (or **line, crest,** or **ridge**) is a long, wide, roughened, posterolaterally placed feature that extends from the base of the greater trochanter to the lateral lip of the linea aspera (see 12.1.1o). It can be a depression or it can assume the form of a true tuberosity. If the latter is present, it is often referred to as the **third trochanter**. It is the insertion for part of the *gluteus maximus muscle*, an extensor, abductor, and lateral rotator of the thigh at the hip that originates on the posterior half of the os coxae, the sacrum, and the coccyx.

k. The **spiral line**, spiraling inferior to the lesser trochanter, connects the inferior end of the intertrochanteric line with the medial lip of the linea aspera. It is the origin of the *vastus medialis muscle*, a part of the *quadriceps femoris muscle*, a knee extensor that inserts on the anterior tibia via the patella.

l. The **pectineal line** is a short, curved line that passes inferolaterally from the base of the lesser trochanter, between the spiral line and gluteal tuberosity. It is the insertion of the *pectineus muscle*, which originates from the pubic part of the os coxae and acts to adduct, laterally rotate, and flex the thigh at the hip.

m. The **femoral shaft** is the long section between the expanded proximal and distal ends of the bone.

n. The **linea aspera** is the long, wide, roughened, and elevated ridge that runs along the posterior shaft surface. It collects the spiral line, pectineal line, and gluteal tuberosity proximally and divides into the medial and lateral supracondyloid ridges distally. The linea aspera is a primary origin site for the *vastus muscles* and the primary insertion site of the adductors (*longus*, *brevis*, and *magnus*) of the hip.

o. The **medial lip of the linea aspera** marks the medial extent of the linea aspera and serves as the site of insertion of *adductor magnus,* and *adductor longus*.

p. The **lateral lip of the linea aspera** marks the lateral border of the linea aspera and serves as the site of insertion of *vastus lateralis*, and the *short head of biceps femoris*.

q. The **nutrient foramen** is located about midshaft level on the posterior surface of the bone, adjacent to or on the linea aspera. This foramen exits the bone distally.

r. The **medial supracondylar line** (or **ridge**) is the inferior, medial extension of the linea aspera, marking the distal, medial corner of the shaft. It is fainter than the lateral supracondylar line.

s. The **lateral supracondylar line** (or **ridge**) is the inferior (distal), lateral extension of the linea aspera. It is more pronounced than the medial supracondylar line.

t. The **popliteal surface** is the wide, flat, triangular area of the posterior, distal femur. It is bounded by the condyles inferiorly and by the supracondylar lines medially and laterally.

u. The **lateral condyle** is the large, protruding, articular knob on the lateral side of the distal femur.

v. The **lateral epicondyle** is the convexity on the lateral side of the lateral condyle. It is an attachment point for the *lateral collateral ligament* of the knee. Its upper surface bears a facet that is an attachment point for one head of the *gastrocnemius muscle*, a flexor of the knee and plantarflexor of the foot at the ankle.

w. The **popliteal groove**, a smooth hollow on the posterolateral side of the lateral condyle, is a groove for the *tendon of the popliteus muscle*. This muscle originates from the impression just anteroinferior to the groove, and it inserts on the posterior tibial surface. *Popliteus* is a medial rotator of the tibia at the knee.

x. The **medial condyle** is the large, articular knob on the medial side of the distal femur. Its medial surface bulges away from the axis of the shaft. The medial condyle extends more distally than the lateral condyle.

y. The **medial epicondyle** is the convexity on the medial side of the medial condyle. It is a point of attachment for the *medial collateral ligament* of the knee.

z. The **adductor tubercle** is a variable, raised tubercle on the medial supracondylar line just superior to the medial epicondyle. It is an attachment point for the *adductor magnus*, a muscle originating on the lower edge of the ischiopubic ramus and ischial tuberosity. This muscle adducts the thigh at the hip.

aa. The **impression for the lateral head of the gastrocnemius** is a shallow depression on the superior edge of the posterior projection of the lateral epicondyle.

ab. The **impression for the popliteus** is a shallow depression on the posterolateral side of the lateral condyle, adjacent to the anteroinferior limit of the popliteal groove.

ac. The **intercondylar fossa**, or **notch**, is the nonarticular, excavated surface between the distal and posterior articular surfaces of the condyles. Within the fossa are two facets that are the femoral attachment sites of the *anterior* and *posterior cruciate ligaments*, a pair of crossed ligaments linking the femur and tibia. These ligaments strengthen the knee joint.

ad. The **intercondylar line** is on the posterior surface of the distal femur, running between the superolateral corner of the medial condyle and the superomedial corner of the lateral condyle. It delineates the boundary between the popliteal surface and the intercondylar fossa (or notch).

ae. The **patellar surface** is a notched articular area on the anterior surface of the distal femur, over which the patella glides during flexion and extension of the knee. The lateral surface of this notch is elevated, projecting more anteriorly than the medial boundary of the notch. This helps prevent lateral dislocation of the patella during full extension of the knee.

af. The **patellar lip** is the raised lateral margin of the patellar surface. The elevated patellar lip of hominids helps to prevent the dislocation of the patella during bipedal locomotion.

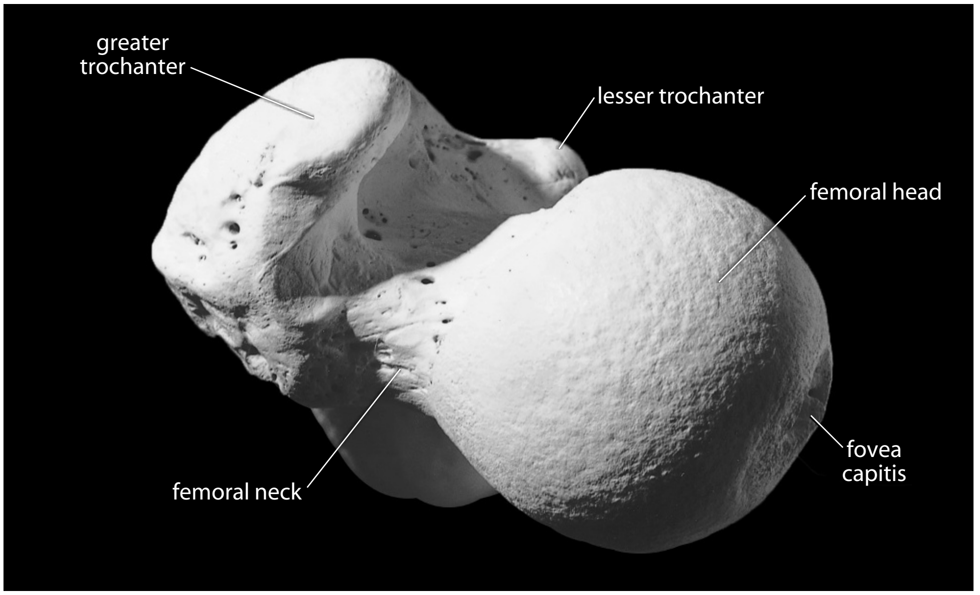

Figure 12.5 **Right femur, proximal**. Posterior is up, lateral is toward the left. Natural size.

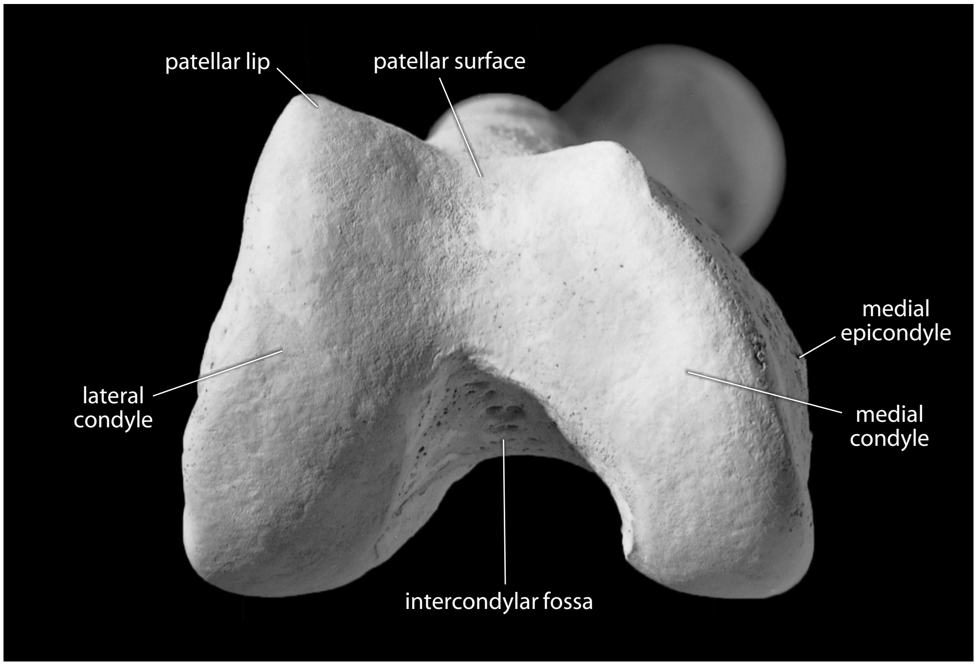

Figure 12.6 **Right femur, distal.** Anterior is up, lateral is toward the left. Natural size.

Figure 12.7 **Femoral, tibial, and fibular growth** *(opposite)*. The pairs of immature femora (*left*), tibiae (*middle*), and fibulae (*right*), shown here in posterior view, are from a one-year old and a six-year-old. Natural size.


1 yr
1 yr
1 yr
6 yrs
6 yrs
6 yrs

12.1.2 Growth (Figure 12.7)

The femur ossifies from five centers: the shaft, the femoral head, the distal end, the greater trochanter, and the lesser trochanter. The femoral head appears at about 6 months to a year. It begins to fuse to the diaphysis at 14–19 years in males, and at about 12–16 years in females. The greater trochanteric epiphysis appears between ages 2–5. It then begins to fuse at 16–18 years in males, and at 14–16 years in females. The lesser trochanteric epiphysis appears between ages 7–12 and then begins to fuse at 16–17 years in both sexes. The distal epiphysis appears just before birth. It begins to fuse with the shaft at about 16–20 years in males, and at about 14–18 years in females (Scheuer and Black, 2000).

12.1.3 Possible Confusion

Neither intact femora nor femoral fragments are easily confused with other bones.

- The femoral head has a fovea and is a more complete sphere than the humeral head.
- The femoral shaft is larger, has a thicker cortex, and is rounder in cross section than any other shaft. It has only one longitudinal feature with sharp edges, the linea aspera (see cross sections in Chapter 14).

12.1.4 Siding

- For intact femora or proximal ends, the head is proximal and faces medially. The lesser trochanter and linea aspera are posterior.
- For isolated femoral heads, the fovea is medial and displaced posteriorly and inferiorly. The posteroinferior head–neck junction is more deeply excavated than the anterosuperior junction.
- For proximal femoral shafts, the nutrient foramen opens distally, and the linea aspera is posterior and thins inferiorly. The gluteal tuberosity is superior and faces posterolaterally.
- For femoral midshafts, the nutrient foramen opens distally, the bone widens distally, and the lateral posterior surface is usually more concave than the medial posterior surface.
- For distal femoral shafts, the shaft widens distally and the lateral supracondylar ridge is more prominent than the medial. The medial condyle extends more distally than the lateral.
- For femoral distal ends, the intercondylar notch is posterior and distal, and the lateral border of the patellar notch is more elevated. The lateral condyle bears the popliteal groove, and the medial condyle bulges away from the line of the shaft. Relative to the shaft axis, the lateral condyle extends more posteriorly than the medial. The medial condyle extends more distally than the lateral because in anatomical position the femur angles beneath the body.

12.1.5 Femoral Measurements (Figure 12.8)

Measurements of the femur are used for stature estimation, age estimation, sex determination, gait reconstruction, biomechanical load calculations, and other analyses.

1. **Maximum femoral length** (Martin, 1928: 1037, #1; Buikstra and Ubelaker, 1994: 82, #60): The maximum length that can be measured between the top of the femoral head and the bottom of the farthest condyle. Measured with an osteometric board.

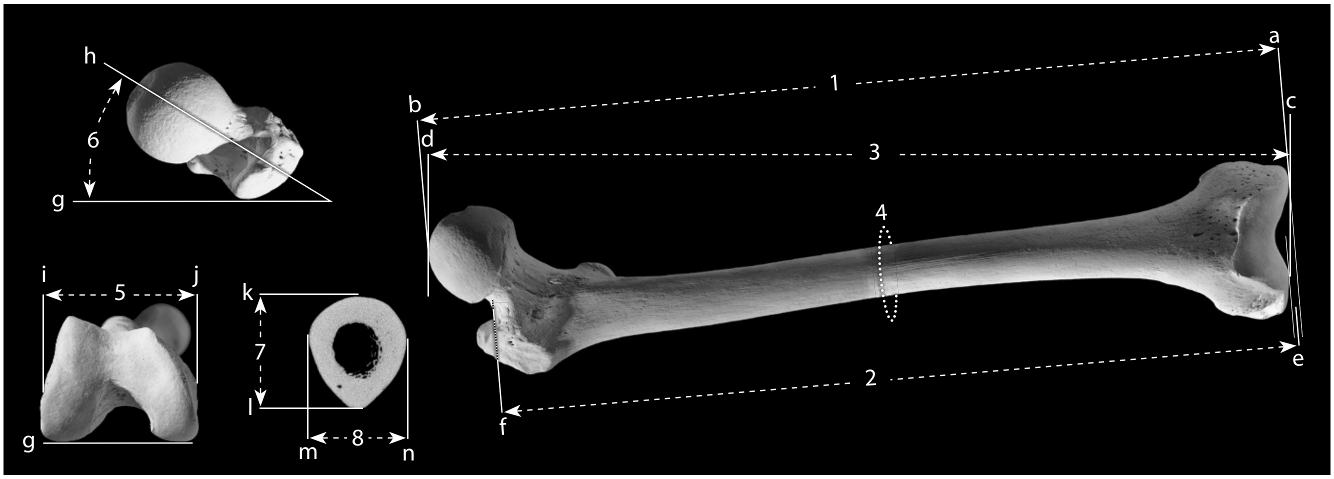

Figure 12.8 **Femoral measurements.** One-fourth (bone) and one-half (CT scan) natural size.

Locations: a) line through inferiormost points of both condyles; b) superiormost point of femoral head; c) point on either condyle that is farthest from 'd'; d) point on femoral head that is farthest from 'c'; e) average of the distance of both condyles from 'f'; f) inferiormost point of superior femoral neck; g) line through posteriormost points of both condyles (*note: condyles are not visible in top left image*); h) longitudinal axis of femoral head and neck; i) lateralmost point on lateral epicondyle; j) medialmost point on medial epicondyle; k) anteriormost point at midshaft; l) posteriormost point at midshaft; m) medialmost point at midshaft; n) lateralmost point at midshaft.

Measurements: 1) maximum femoral length; 2) femoral biomechanical length; 3) femoral bicondylar (or physiological) length; 4) femoral midshaft circumference; 5) femoral epicondylar breadth; 6) femoral torsion; 7) femoral anteroposterior midshaft diameter; 8) femoral mediolateral midshaft diameter.

2. **Femoral biomechanical length** (Trinkaus et al., 1999: 757): Using a large sliding caliper, place the stationary jaw on the inferiormost point of the superior femoral neck, and then measure the distances to: 1) the distalmost point of the medial condyle; and 2) the distalmost point of the lateral condyle. Biomechanical length is the average of these two distances.
3. **Femoral bicondylar** (or **physiological**) **length** (Martin, 1928: 1037–1037, #2; Buikstra and Ubelaker, 1994: 82, #61): Place both condyles firmly against the stationary end of an osteometric board and, while keeping the shaft of the femur parallel to the surface of the board, measure the distance to the furthest point on the femoral head.
4. **Femoral midshaft circumference** (Martin, 1928: 1040, #8; Buikstra and Ubelaker, 1994: 83, #68): Determine the location of midshaft (preferably using 50% of femoral biomechanical length) and use a flexible cloth tape to determine the minimum circumference at that location.
5. **Femoral epicondylar breadth** (Martin, 1928: 1041, #21; Buikstra and Ubelaker, 1994: 82, #62): With a sliding caliper or an osteometric board, measure the distance between the medialmost and lateralmost points on the epicondyles.
6. **Femoral torsion** (Martin, 1928: 1043, #28): Place the femur posterior-side-down on a flat table so that it rests stably on three points: the posteriormost points of each condyle and the posteriormost point of the greater trochanter. Using a goniometer or protractor, measure the angle formed between the longitudinal axis of the femoral neck (and head) and the table.
7. **Femoral anteroposterior** (or **sagittal**) **midshaft diameter** (Martin, 1928: 1039: #6; Buikstra and Ubelaker, 1994: 83, #66): Determine the location of midshaft (preferably 50% of femoral biomechanical length) and use a sliding caliper to determine the anteroposterior dimension at that point (including the linea aspera).

8. **Femoral mediolateral** (or **transverse**) **midshaft diameter** (Martin, 1928: 1039: #7; Buikstra and Ubelaker, 1994: 83, #67): At the same midshaft location as above, use a sliding caliper to determine the mediolateral dimension at that point (the caliper should be perpendicular to the position used to measure the anteroposterior diameter).
9. **Platymeric index** (Martin, 1928: 1045): (anteroposterior midshaft diameter ÷ mediolateral midshaft diameter) × 100.

12.1.6 Femoral Nonmetric Traits

- **Third trochanter**: In some individuals a rounded tubercle (often resembling the lesser trochanter in form) develops above, or instead of, the gluteal tuberosity. This feature is usually scored as 0 (absent), 1 (present), or 2 (ridge).
- **Fovea capitis shape**: Examine and record the shape of the margins of the fovea capitis. The scoring possibilities are 0 (absent), 1 (round), 2 (oval), 3 (triangular), or 4 (irregular).
- **Femoral bowing**: Note the presence and degree of lateral bowing in the femoral shaft. Usually scored as 1 (straight), 2 (slight), 3 (medium), or 4 (marked).
- **Allen's fossa and Poirier's facet** (or **extension**): Allen's fossa, Poirier's facet, and plaque formation are all defects of the margin of the femoral head. Allen's fossa is found anterosuperiorly, and requires that underlying trabeculae be visible to be scored as present. Poirier's facet is a slight lateral bulging of the articular surface of the femoral head on the anterosuperior neck. The surface of a Poirier's facet is smooth, while that of an Allen's fossa is rough. Plaque formation (or extension) is a bony overgrowth or scar extending from the area of a Poirier's facet. This complex of interrelated features is usually scored as 0 (absent), 1 (fossa), 2 (porous), 3 (ulcer), 4 (plaque), 5 (Poirier's facet), 6 (Allen's fossa and Poirier's facet), or 7 (Allen's fossa and Poirier's facet and plaque). The main individual used to illustrate this book has a slight Poirier's facet (visible in Figures 12.1, 12.4, and 12.5).
- **Anterior femoral neck torsion** (or **femoral anteversion**): Measure the degree of femoral torsion as defined above and score as follows: 0 (< 10°), 1 (10°–15°), 2 (16°–25°), or 3 (>25°).

12.2 Patella (Figures 12.9–12.10)

12.2.1 Anatomy

The patella, the largest sesamoid bone in the body, articulates only with the patellar surface of the distal femur (patellar notch). The patella rides in the *tendon of the quadriceps femoris*—the largest muscle of the thigh and the primary extensor of the knee. The patella functions to protect the knee joint, to lengthen the lever arm of the *quadriceps femoris*, and to increase the area of contact between the *patellar ligament* and the femur.

a. The **apex** of the patella is the nonarticular tip of the bone. It points distally.
b. The **lateral articular facet** for the distal femur faces posteriorly and is the largest part of the large articular surface of the patella.
c. The **medial articular facet** for the distal femur faces posteriorly and is smaller than the lateral articular facet.
d. The **base** of the patella is the blunt, nonarticular proximal end of the bone, opposite the apex.

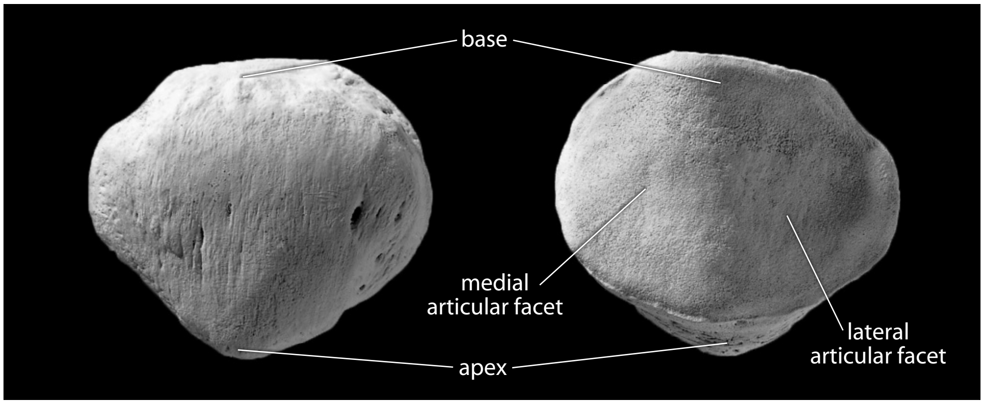

Figure 12.9 **Right patella.** *Left:* anterior view; superior is up, lateral is toward the left. *Right:* posterior view; superior is up, lateral is toward the right. Natural size.

12.2.2 Growth

The patella ossifies from a single center that generally first appears at about 3–6 years (Scheuer and Black, 2000).

12.2.3 Possible Confusion

This bone might be mistaken for an os coxae fragment, but only in a very fragmentary state. The acetabulum of the os coxae is strongly hollowed, as opposed to the much flatter articular surface of the patella.

12.2.4 Siding

- **Anatomical siding**. The patella is triangular in shape. Its thin, pointed apex is distal, and the thicker, blunter end is proximal. The lateral articular facet, which articulates with the lateral condyle of the femur, is the larger of the two facets.
- **Positional siding**. Place the apex away from you and the articular surface on the table. The bone falls toward the side from which it comes.

12.2.5 Patellar Measurements (Figure 12.10)

Measurements of the patella are infrequently used in biomechanical analyses of the patellofemoral joint.

1. **Maximum patellar height** (Martin, 1928: 1048, #1): Using a sliding caliper or an osteometric board, determine the maximum distance between the base and the apex of the patella.
2. **Maximum patellar breadth** (Martin, 1928: 1048, #2): Using a sliding caliper or an osteometric board, determine the maximum breadth of the patella, perpendicular to maximum patellar height.

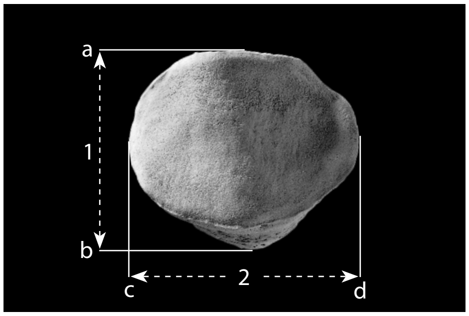

Figure 12.10 **Patellar measurements.** Two-thirds natural size.
Locations: a) point on base farthest from apex; b) point on apex farthest from base; c) point on medial edge farthest from the maximum height chord, $\overline{ab}$; d) point on lateral edge farthest from ‘c,’ keeping $\overline{cd}$ perpendicular to $\overline{ab}$.
Measurements: 1) maximum patellar height; 2) maximum patellar breadth.

12.2.6 Patellar Nonmetric Traits

- **Vastus notch**: There may be a small notch on the superolateral margin of the patella. This vastus notch should only be scored as present when its borders are smooth. If the borders are rough, as if the missing bone had been torn away, the notch is considered emarginate. Usually scored as 0 (absent), 1 (present), or 2 (emarginate). The patella shown in Figures 12.9 and 12.10 has a vastus notch.
- **Vastus fossa** (or **facet**): Along the superolateral margin of the anterior patella, there may be a small depression (either just anterior to the vastus notch or appearing without a vastus notch). This trait is usually scored as 0 (absent), or 1 (present).
- **Cleft patella** (or **patella partita**): In some individuals, the patella is divided into two or more portions during life, possibly as a result of trauma or an overuse injury.
- **Patellar spurs**: Note whether the patella has any bony spurs. Usually scored as 0 (absent), or 1 (present). It appears that spur formation may be associated with a rupture of the *quadriceps tendon* (Hardy et al., 2005).

12.3 Tibia (Figures 12.11–12.17)

12.3.1 Anatomy

The tibia is the major weight-bearing bone of the lower leg. It articulates proximally with the distal femur, twice laterally with the fibula (once proximally and once distally), and distally with the talus.

a. The **tibial plateau** is the proximal tibial surface on which the femur rests. It is divided into two articular sections, one for each femoral condyle. In life there are fibrocartilaginous rings around the periphery of these articular facets, the *medial* and *lateral menisci*.
b. The **medial condyle** is the medial part of the tibial plateau. Its femoral articulation is oval, with the long axis oriented anteroposteriorly. Its lateral edge is straight.
c. The **lateral condyle** is the lateral part of the tibial plateau. Its femoral articulation is smaller and rounder than the medial articulation.
d. The **intercondylar eminence** is the raised area on the proximal tibial surface between articular facets.
e. The **medial intercondylar tubercle** forms the medial part of the intercondylar eminence.

f. The **lateral intercondylar tubercle** forms the lateral part of the intercondylar eminence. The *anterior* and *posterior cruciate ligaments* and the anterior and posterior extremities of the *menisci* insert into the nonarticular areas between the condyles, which are just anterior and posterior to the medial and lateral intercondylar tubercles, respectively.

g. The **anterior intercondylar area** is the nonarticular area on the tibial plateau anterior to the intercondylar eminence. It serves as an attachment site for the *anterior cruciate ligament* and the anterior ends of both *menisci*.

h. The **posterior intercondylar area** is the nonarticular area posterior to the intercondylar eminence. It serves as an attachment site for the *posterior cruciate ligament* and the posterior ends of both *menisci*.

i. The **superior fibular articular facet** is located on the posteroinferior edge of the lateral condyle.

j. The **groove for the semimembranosus** is an anteroposteriorly elongated hollow on the medial side of the medial condyle.

k. The **tibial tuberosity** is the rugose area on the anterior surface of the proximal tibia. Its superior part is smoothest and widest. The *patellar ligament* of the *quadriceps femoris muscle*, a major lower leg extensor at the knee, inserts here.

l. The tibial **shaft** (or **body**) is the fairly straight segment of the tibia between the expanded proximal and distal ends. The shaft is divided into three named surfaces by three named borders (or margins).

m. The **medial surface** of the shaft forms the medial edge of the "shin" of the lower leg. This subcutaneous, anteromedially facing surface is the widest tibial shaft surface.

n. The **posterior surface** runs along the entire length of the shaft. The broad, flat area/ portion of the posterior surface closest to the knee is often called the **popliteal surface**, although it is still part of the posterior surface. The soleal (or popliteal) line runs across the popliteal surface.

o. The **lateral** (or **interosseous**) **surface** of the shaft lies opposite the fibula. It is the most concave of the three tibial surfaces.

p. The **medial border** (or **margin** or **crest**) is the blunt edge running along the medial side of the shaft. It is the one of the three crests that give much of the tibial shaft its prismatic outline, and it serves as the attachment site of the *deep transverse fascia*.

q. The **anterior border** (or **margin** or **crest**) of the shaft forms the anterior edge of the "shin." It is the most prominent of the three crests that give much of the tibial shaft its distinctive prismatic (triangular) outline.

r. The **interosseous border** (or **margin** or **crest**) is the lateral crest of the shaft, which faces the fibula. It is the last of the three main crests of the tibial shaft, and it is the attachment area for the *interosseous membrane*, a sheet of tissue that functions to bind the tibia and fibula together and to compartmentalize lower leg muscles into anterior and posterior groups, just as its serial homolog does in the forearm.

s. The **soleal** (or **popliteal**) **line** crosses the proximal one-third to one-half of the posterior tibial surface from superolateral to inferomedial. The line demarcates the inferior boundary of the *popliteus muscle* insertion. This muscle is a flexor and medial rotator of the tibia and originates from the popliteal groove on the lateral femoral condyle. The line itself gives rise to the *popliteus fascia* and *soleus muscle*, a plantarflexor of the foot at the ankle.

t. The **nutrient foramen** is just inferolateral to the popliteal line. It is a large foramen that exits the bone proximally.

u. The **vertical line** arises just inferior to the soleal (or popliteal) line and divides the posterior surface roughly in half. It marks the boundary between the origins of the *tibialis posterior* and *flexor digitorum longus muscles*.

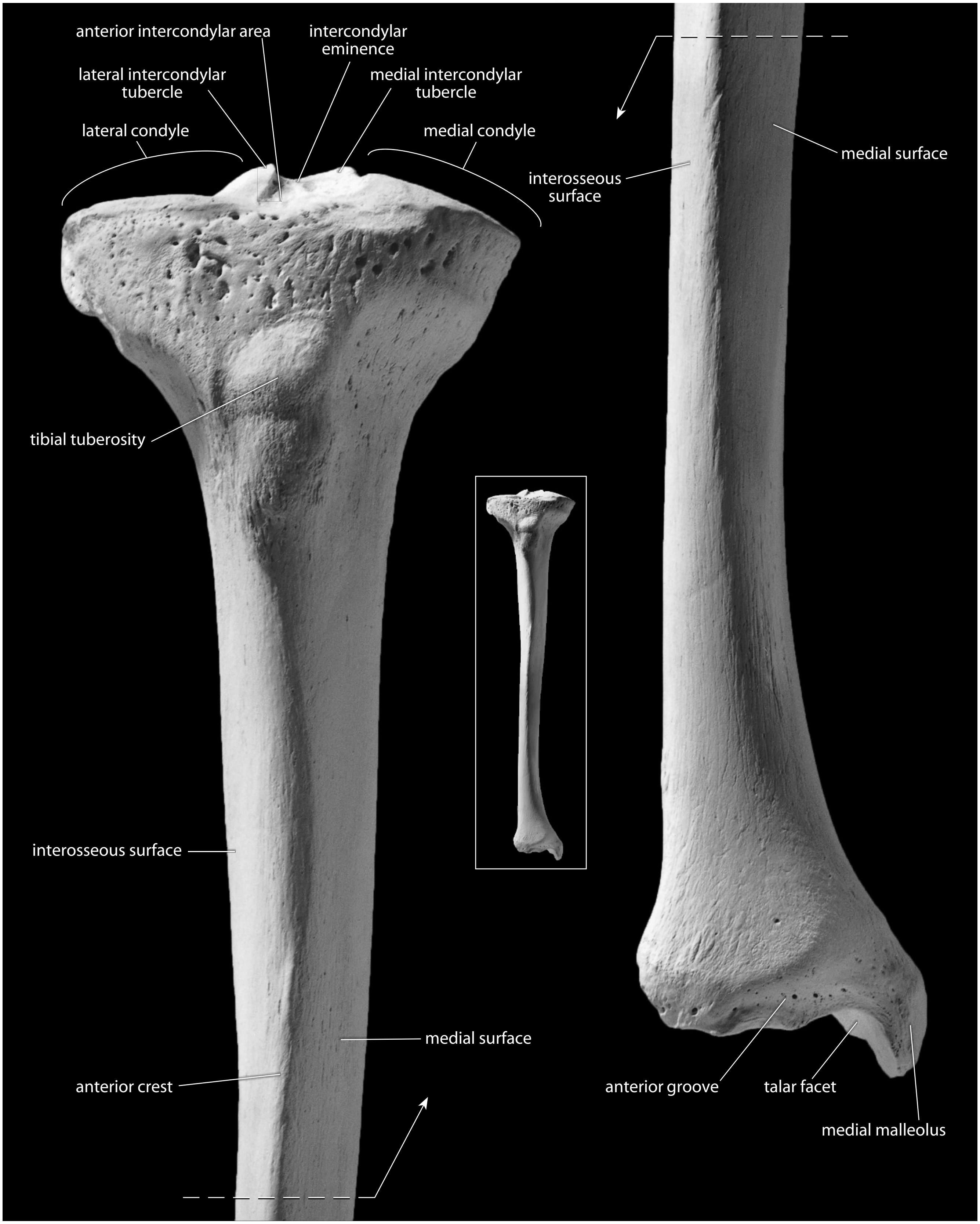

Figure 12.11 **Right tibia, anterior.** *Left:* proximal end; *right:* distal end. Natural size.

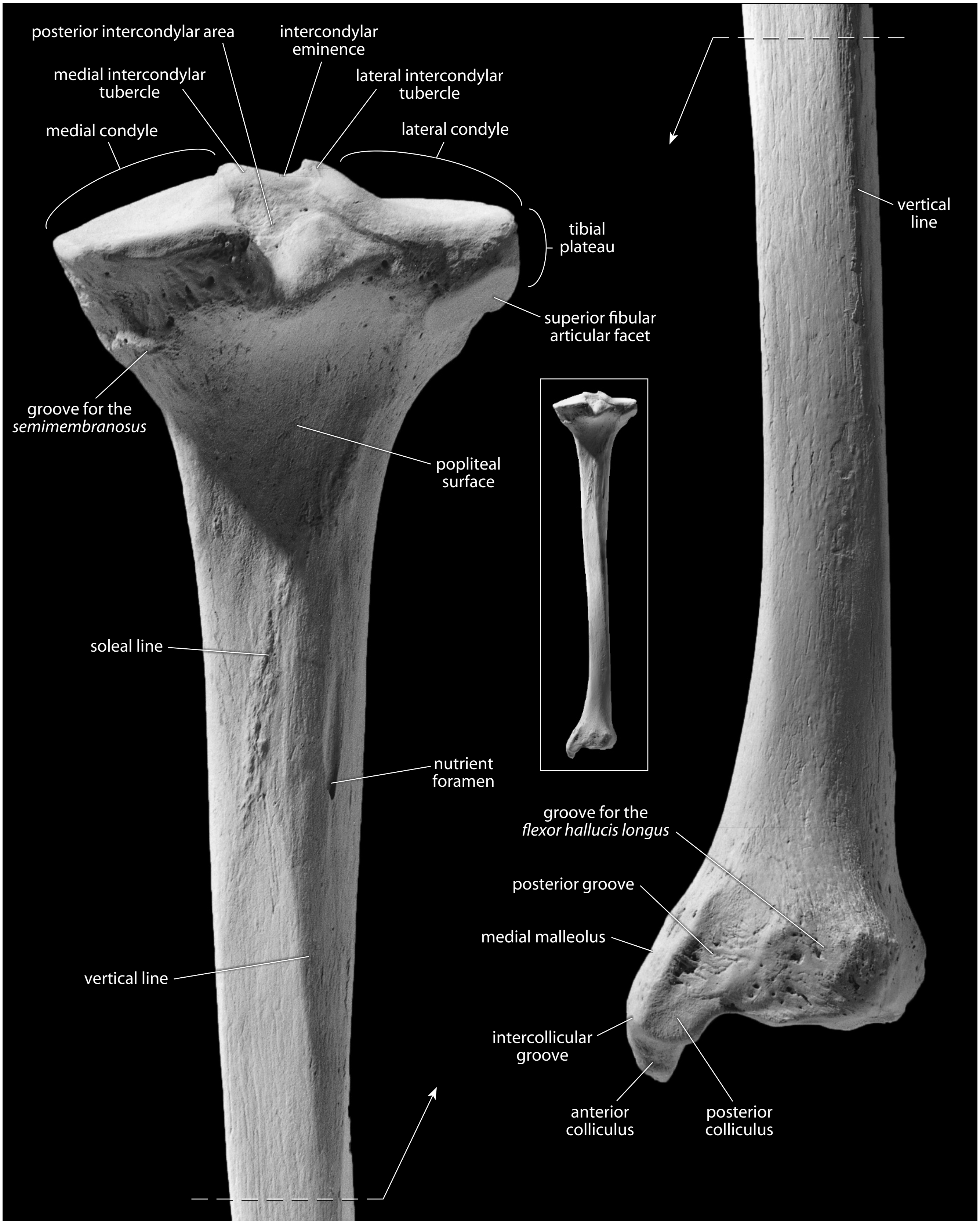

Figure 12.12 **Right tibia, posterior.** *Left:* proximal end; *right:* distal end. Natural size.

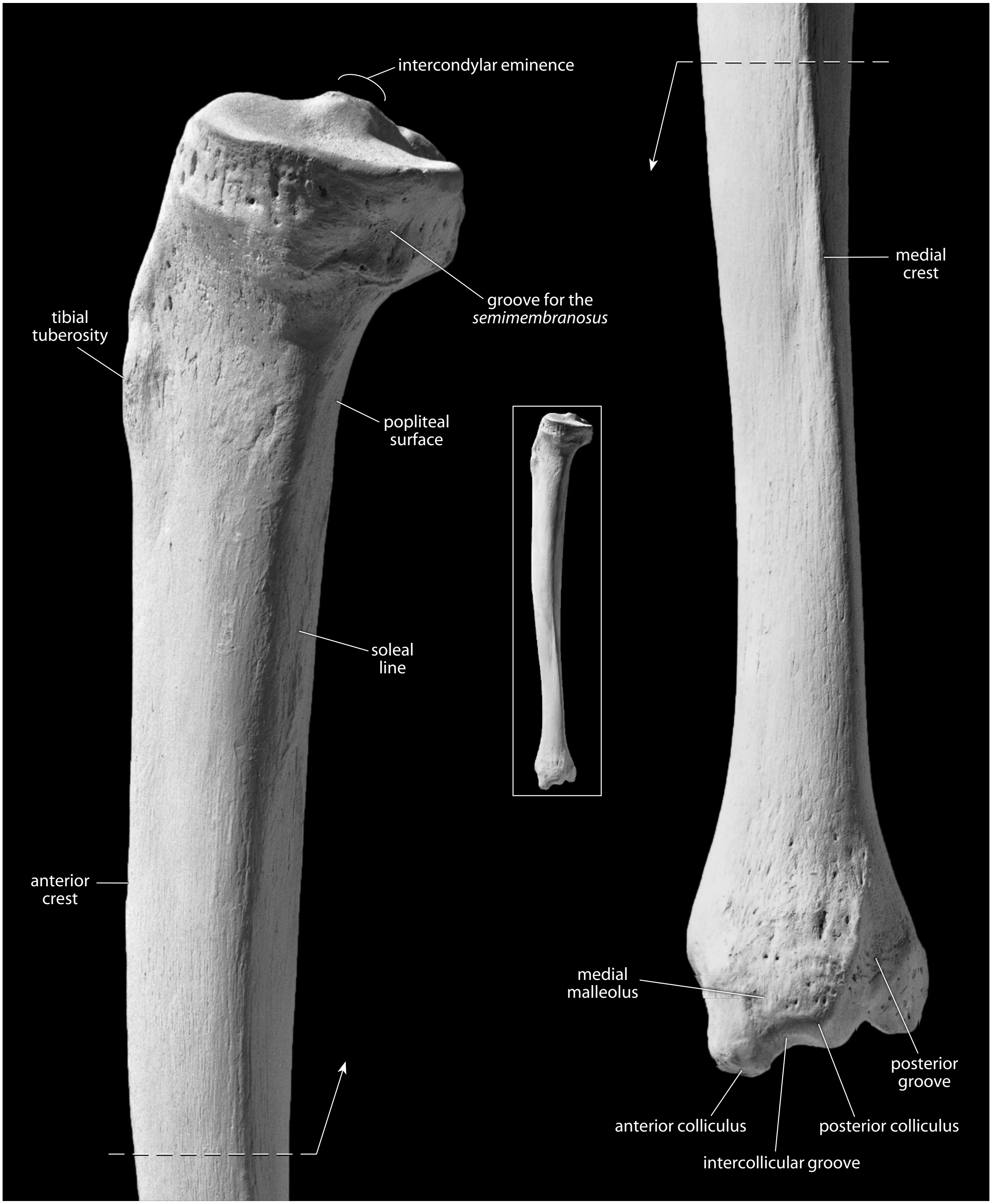

Figure 12.13 **Right tibia, medial.** *Left:* proximal end; *right:* distal end. Natural size.

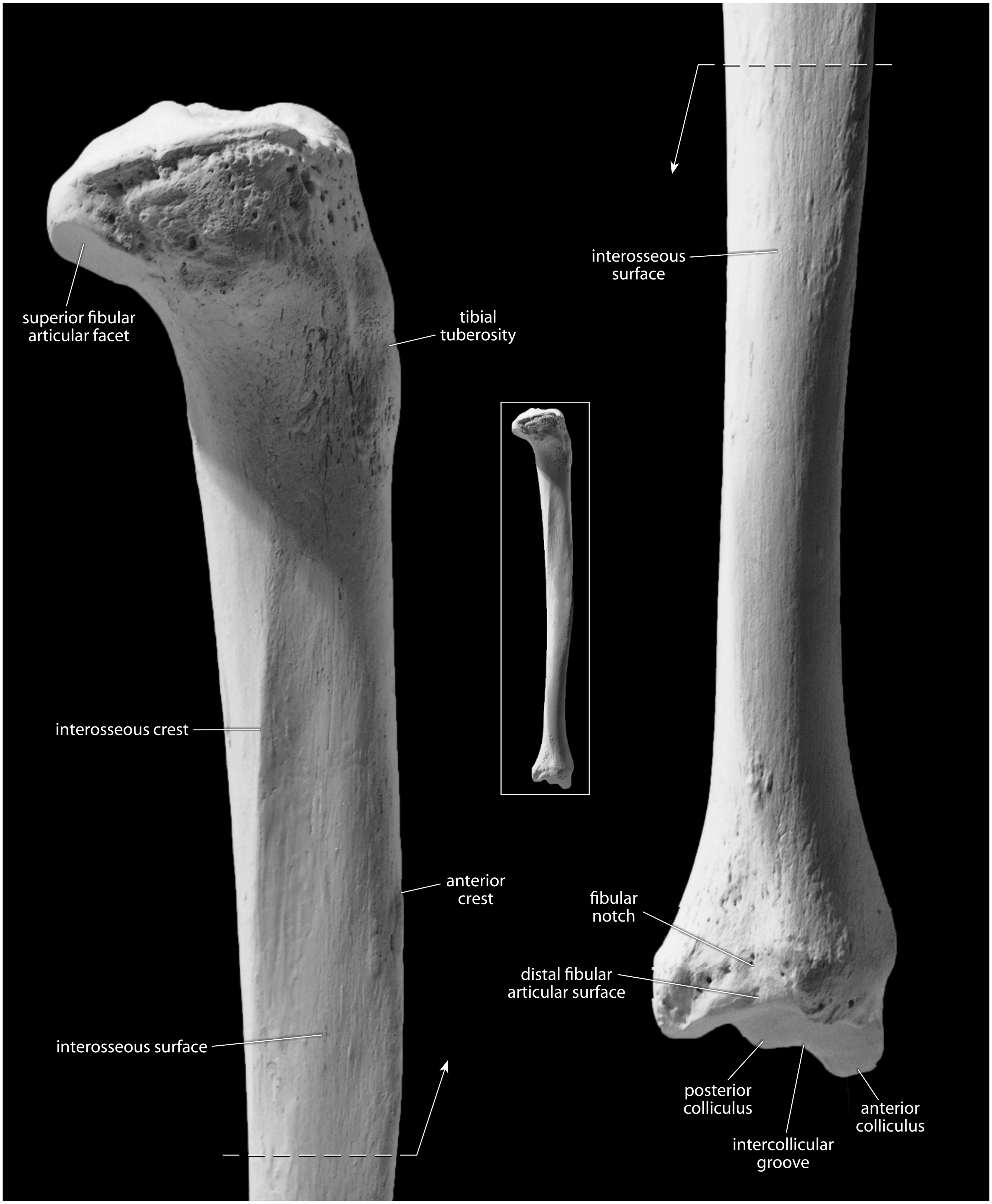

Figure 12.14 **Right tibia, lateral.** *Left:* proximal end; *right:* distal end. Natural size.

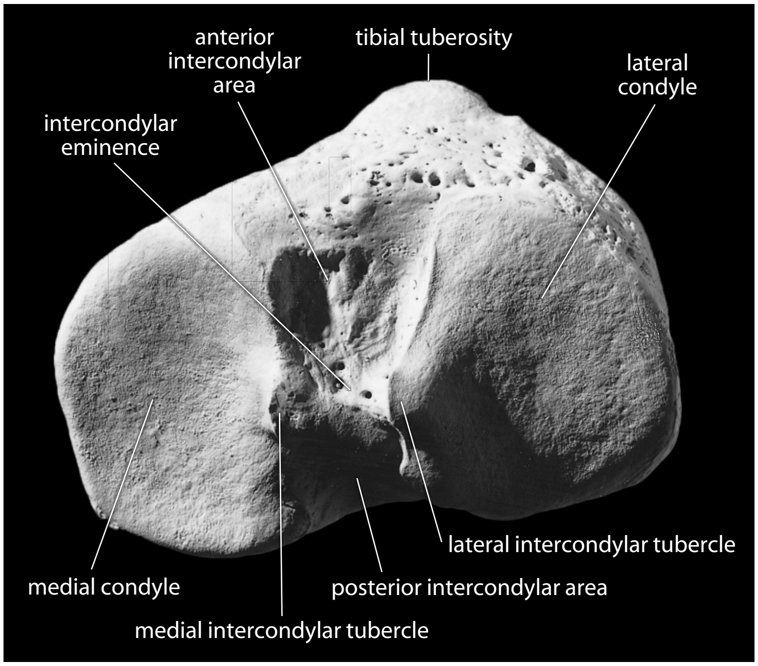

Figure 12.15 **Right tibia, proximal.** Anterior is up, lateral is toward the right. Natural size.

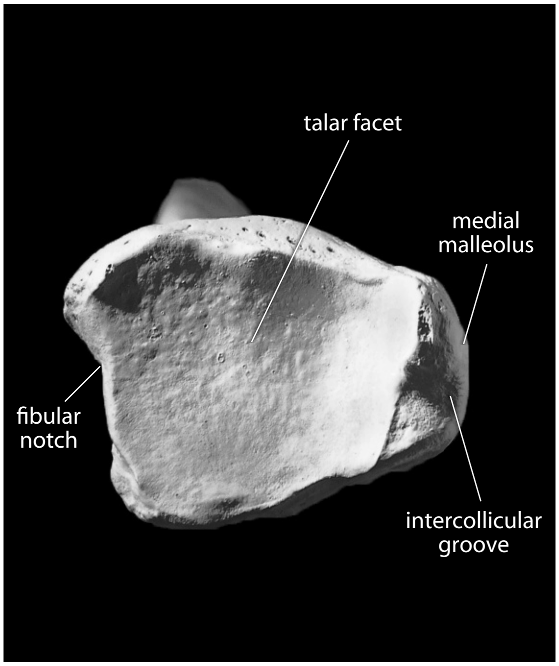

Figure 12.16 **Right tibia, distal.** Anterior is up, lateral is toward the left. Natural size.

v. The **medial malleolus** is the projection on the medial side of the distal tibia that forms the subcutaneous medial knob at the ankle. Its lateral surface articulates with the talar body. The medial malleolus is comprised of two rounded, hill-like prominences: the larger **anterior colliculus** and the smaller **posterior colliculus**.

w. The **intercollicular groove** separates the anterior and posterior colliculi. The groove and both colliculi serve as attachment sites for the apex of the *deltoid ligament.*

x. The **anterior groove** is a short but pronounced horizontal groove on the anterior aspect of the distal shaft, immediately superior to the talar articular surface.

y. The **fibular notch** is the distolateral corner of the tibia. It is a triangular nonarticular area for the thick, short interosseous *tibiofibular ligament*. This ligament binds the distal tibia and fibula together as a unit at this syndesmosis. The proximal ankle, or **talocrural**, joint is formed by the tightly bound distal tibia and fibula, which articulate with the superior, medial, and lateral talar surfaces.

z. The **distal fibular articular surface** is a thin articular surface for the fibula, which faces laterally at the base of the fibular notch.

aa. The **posterior** (or **malleolar**) **groove** on the posterior aspect of the medial malleolus transmits the *tendons of the tibialis posterior* and *flexor digitorum longus muscles*, both plantarflexors.

ab. The **groove for the flexor hallucis longus** is a shallow groove found on the distalmost portion of the posterior tibia. It is less pronounced than the posterior (or malleolar) groove.

ac. The **talar articular surface** is composed of both the saddle-shaped, inferior-facing (superior) talar surface and the much smaller medial talar surface.

12.3.2 Growth (Figure 12.7)

The tibia ossifies from three centers: the diaphysis, the proximal epiphysis (including the tibial tuberosity), and the distal epiphysis. The primary center of ossification in the diaphysis appears appears at about 7–8 weeks (*in utero*). The secondary ossification center in the proximal epiphysis appears at 36 weeks (*in utero*) to 2 months (postnatal). It begins to fuse to the diaphysis at 13–17 years in females, and at about 15–19 years in males. The ossification center in the tibial tuberosity appears at 8–12 years in females and at about 9–14 years in males. The tibial tuberosity begins to fuse to the proximal epiphysis at about 12–14 years in both sexes. The secondary ossification center in the distal epiphysis appears at 3–10 months. It begins to fuse to the diaphysis at 14–16 years in females and at about 15–18 years in males (Scheuer and Black, 2000).

12.3.3 Possible Confusion

- The triangular tibial cross section differentiates fragments of this bone from the femur or the much smaller humerus (see cross sections in Chapter 14). The tibial shaft is much larger than radial or ulnar shafts.
- Proximal and distal ends of the tibia are diagnostic, and the only possibility of confusion arises in mistaking a segment of the proximal articular surface for the body of a vertebra. The articular surface of the tibia is much denser and smoother than the articular surface of a vertebral body.

12.3.4 Siding

- For an intact tibia, the tibial tuberosity is proximal and anterior. The medial malleolus is on the distal end and is medial.
- For the proximal tibia, the tibial tuberosity is anterolateral, the fibular articulation is placed posterolaterally, and the lateral femoral articular surface is smaller, rounder, and set laterally. The intercondylar eminence is set posteriorly, and the axis of the nonarticular strip on the plateau runs from anterolateral to posteromedial. This strip is wider anteriorly than posteriorly. The intercondylar eminence has a more concave medial border and a more evenly sloping lateral border.
- For fragments of the shaft, the entire shaft tapers distally, and the interosseous border is lateral and posterior. The medial surface is the widest surface and faces anteriorly. The lateral surface is the most concave surface. The nutrient foramen is posterior and exits proximally. The cortex is thickest at midshaft.
- For the distal end, the malleolus is medial and its distalmost projection is anterior. Grooves for the plantarflexor tendons are posterior. The fibular notch is lateral, and the interosseous border runs toward its anterior surface. The margin of the articular surface for the superior talus is grooved on the anterior surface but not the posterior surface. The anterior colliculus is larger than the posterior colliculus.

12.3.5 Tibial Measurements (Figure 12.17)

Measurements of the tibia are used for stature estimation, age estimation, sex determination, gait reconstruction, biomechanical load calculations, and other analyses.

1. **Maximum tibial length** (Martin, 1928: 1049, #1a; Buikstra and Ubelaker, 1994: 83, #69): The maximum length that can be measured between the top of the intercondylar eminence and the bottom of the medial malleolus. Measured with an osteometric board.

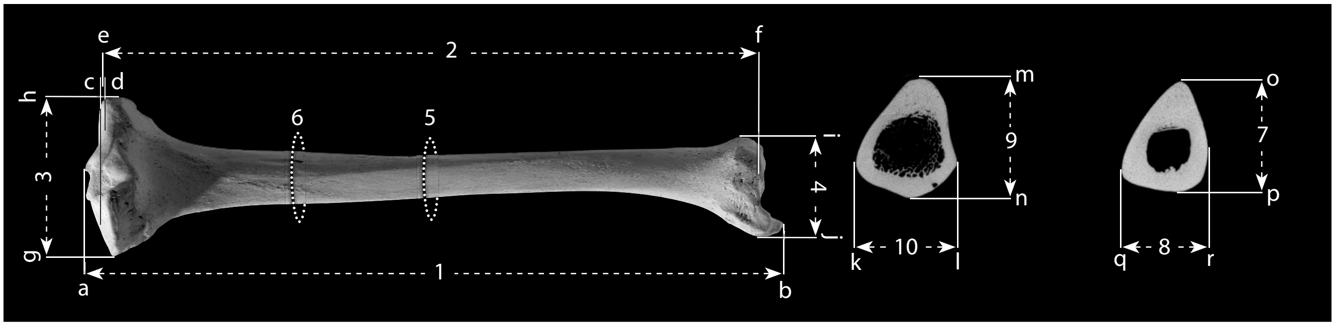

Figure 12.17 **Tibial measurements.** One-fourth (bone) and one-half (CT scan) natural size.

Locations: a) superiormost point of intercondylar eminence; b) inferiormost point of medial malleolus; c) centerpoint of medial condyle; d) centerpoint of lateral condyle; e) average of the distance of both condyle centerpoints from 'f'; f) centerpoint of talar articular surface; g) medialmost point of tibial plateau; h) lateralmost point of tibial plateau; i) lateralmost point of distal epiphysis; j) medialmost point of medial malleolus; k) medialmost point of shaft at level of nutrient foramen; l) lateralmost point of shaft at level of nutrient foramen; m) anteriormost point of shaft at level of nutrient foramen; n) posteriormost point of shaft at level of nutrient foramen; o) anteriormost point at midshaft; p) posteriormost point at midshaft; q) medialmost point at midshaft; r) lateralmost point at midshaft.

Measurements: 1) maximum tibial length; 2) tibial biomechanical length; 3) tibial maximum proximal epiphyseal breadth; 4) tibial maximum distal epiphysis breadth; 5) tibial midshaft circumference; 6) tibial circumference at nutrient foramen; 7) tibial anteroposterior midshaft diameter; 8) tibial mediolateral midshaft diameter; 9) tibial maximum shaft diameter at nutrient foramen; 10) tibial mediolateral (or transverse) shaft diameter at nutrient foramen.

2. **Tibial biomechanical length** (Trinkaus et al., 1999: 757): Using a large sliding caliper, place the tip of the stationary jaw on the centerpoint of the talar articular surface, and then measure the distances to: 1) the centerpoint of the medial condyle; and 2) the centerpoint of the lateral condyle. Biomechanical length is the average of these two distances.
3. **Tibial maximum proximal epiphyseal breadth** (Buikstra and Ubelaker, 1994: 83, #70): Using sliding calipers or an osteometric board, determine the maximum distance between the medialmost and lateralmost points of the tibial plateau.
4. **Tibial maximum distal epiphyseal breadth** (Buikstra and Ubelaker, 1994: 83, #71): Using sliding calipers or an osteometric board, determine the maximum distance between the medialmost point on the medial malleolus and the lateralmost point on the distal epiphysis.
5. **Tibial midshaft circumference** (Martin, 1928, 1050, #10): Determine the location of midshaft (preferably using 50% of tibial biomechanical length) and use a flexible cloth tape to determine the minimum circumference at that location.
6. **Tibial circumference at nutrient foramen** (Martin, 1928, 1050, #10a; Buikstra and Ubelaker, 1994: 83, #74): With a flexible cloth tape, measure the minimum circumference at the level of the nutrient foramen.
7. **Tibial anteroposterior midshaft diameter** (Martin, 1928, 1050, #8): Determine the location of midshaft (preferably using 50% of tibial biomechanical length) and use a sliding caliper to determine the anteroposterior diameter at that location.
8. **Tibial mediolateral** (or **transverse**) **midshaft diameter** (Martin, 1928, 1050, #9): Determine the location of midshaft (preferably using 50% of tibial biomechanical length) and use a sliding caliper to determine the mediolateral diameter at that location.
9. **Tibial maximum shaft diameter at nutrient foramen** (Martin, 1928, 1050, #8a; Buikstra and Ubelaker, 1994: 83, #72): With the bone in anatomical position and the sliding caliper in a parasagittal plane, measure the greatest distance from the anterior border to the posterior surface at the level of the nutrient foramen.

10. **Tibial mediolateral** (or **transverse**) **shaft diameter at nutrient foramen** (Martin, 1928, 1050, #9a; Buikstra and Ubelaker, 1994: 83, #73): With the bone in anatomical position and the sliding caliper in a paracoronal plane, measure the maximum mediolateral dimension of the shaft at the level of the nutrient foramen.
11. **Platycnemic index** (Martin, 1928: 1052): (mediolateral shaft diameter at nutrient foramen $\div$ maximum shaft diameter at nutrient foramen) $\times$ 100.

12.3.6 Tibial Nonmetric Traits

- **Tibial squatting facet**: In individuals who habitually spend time in an extremely dorsiflexed position (*e.g.,* sitting in a deep squatting position), a pair of conforming facets may form on the approximated anteroinferior tibia and anterosuperior talus. The tibial facet is usually scored as 0 (absent) or 1 (present).
- **Platycnemia** (or **saber shins**): In some individuals, the tibia may be noticeably flattened mediolaterally, a condition called platycnemia. A platycnemic tibia is one which has a platycnemic index of less than 63 (Bass, 2005).
- **Tibial bowing**: There are three types of tibial bowing, each characterized by the direction to which the apex of the bowing points: anterolateral, anteromedial, and posteromedial. Note the direction of the most severe degree of bowing and score it as 1 (straight), 2 (slight), 3 (moderate), or 4 (marked).

12.4 Fibula (Figures 12.18–12.23)

12.4.1 Anatomy

The fibula is a long, thin bone that lies lateral to the tibia, articulating twice with it and once with the talus. Although this bone plays only an indirect role in the knee joint, serving to anchor ligaments, it plays a key role in forming the lateral border of the ankle joint. The fibula bears very little weight, not even touching the femur at its superior end.

a. The **fibular head** is the swollen proximal end of the fibula, more massive and less mediolaterally flattened than the distal end. It is the attachment point for the *biceps femoris muscle* (a flexor and lateral rotator at the knee) and the *lateral collateral ligament* of the knee.
b. The **styloid process** (or **apex**) is the most proximal projection of the bone, forming the posterior part of the head.
c. The **proximal fibular articular surface** is a round, flat, medially oriented surface that corresponds to a similar surface on the lateral proximal tibia.
d. The **fibular neck** extends from the shaft and flares proximally to meet the fibular head.
e. The fibular **shaft** is the long, thin, fairly straight segment of the bone between the expanded proximal and distal ends. The shaft is divided into three named surfaces by three named borders (or margins).
f. The **anterior border** (or **margin** or **crest**) lies between the medial and lateral surfaces.
g. The **lateral surface** faces laterally and somewhat anteriorly. The lateral surface lies between the anterior and posterior borders.
h. The **posterior border** (or **margin** or **crest**) faces posterolaterally and lies between the lateral and posterior surfaces.

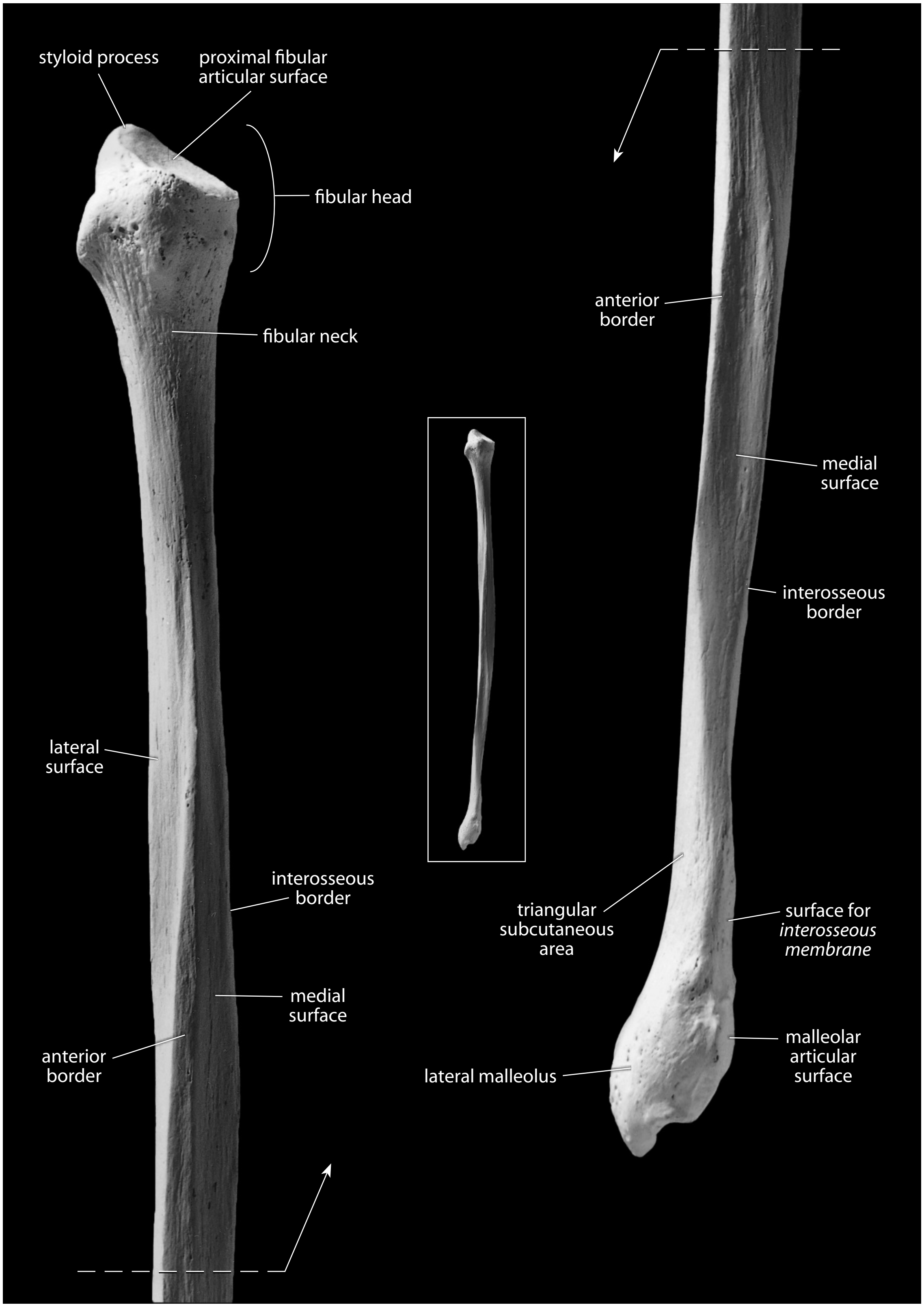

Figure 12.18 **Right fibula, anterior.** *Left:* proximal end; *right:* distal end. Natural size.

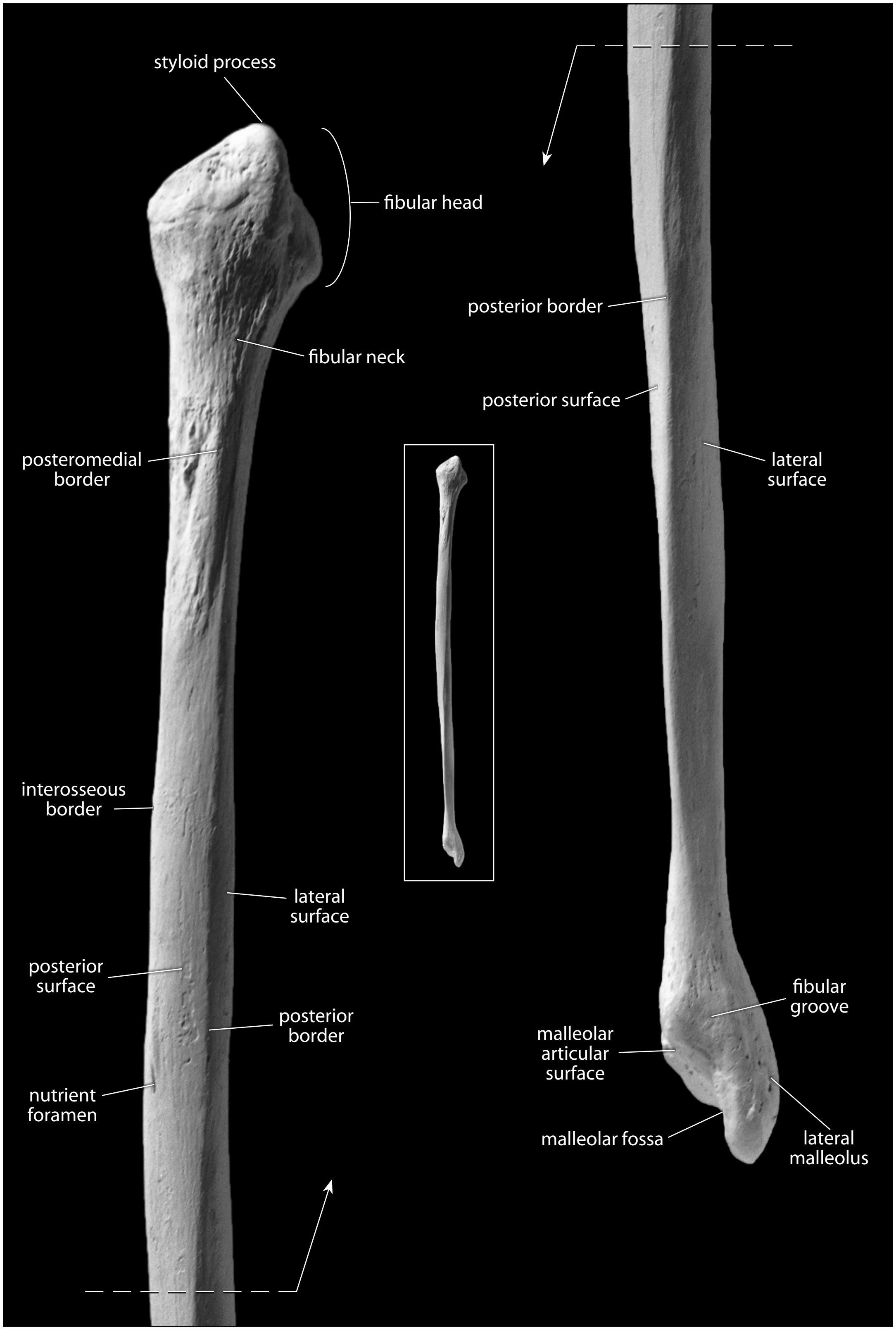

Figure 12.19 **Right fibula, posterior.** *Left:* proximal end; *right:* distal end. Natural size.

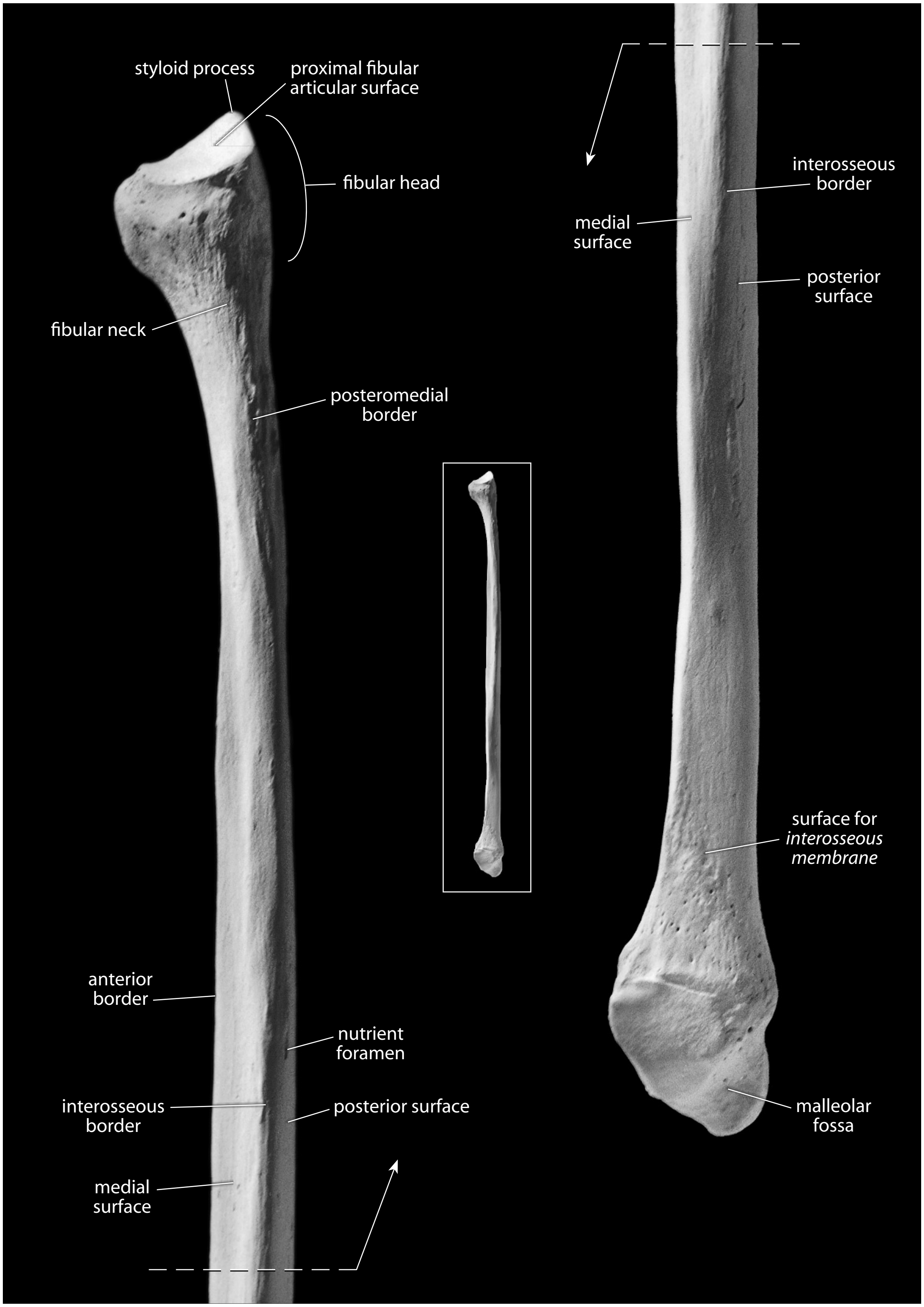

Figure 12.20 **Right fibula, medial.** *Left:* proximal end; *right:* distal end. Natural size.

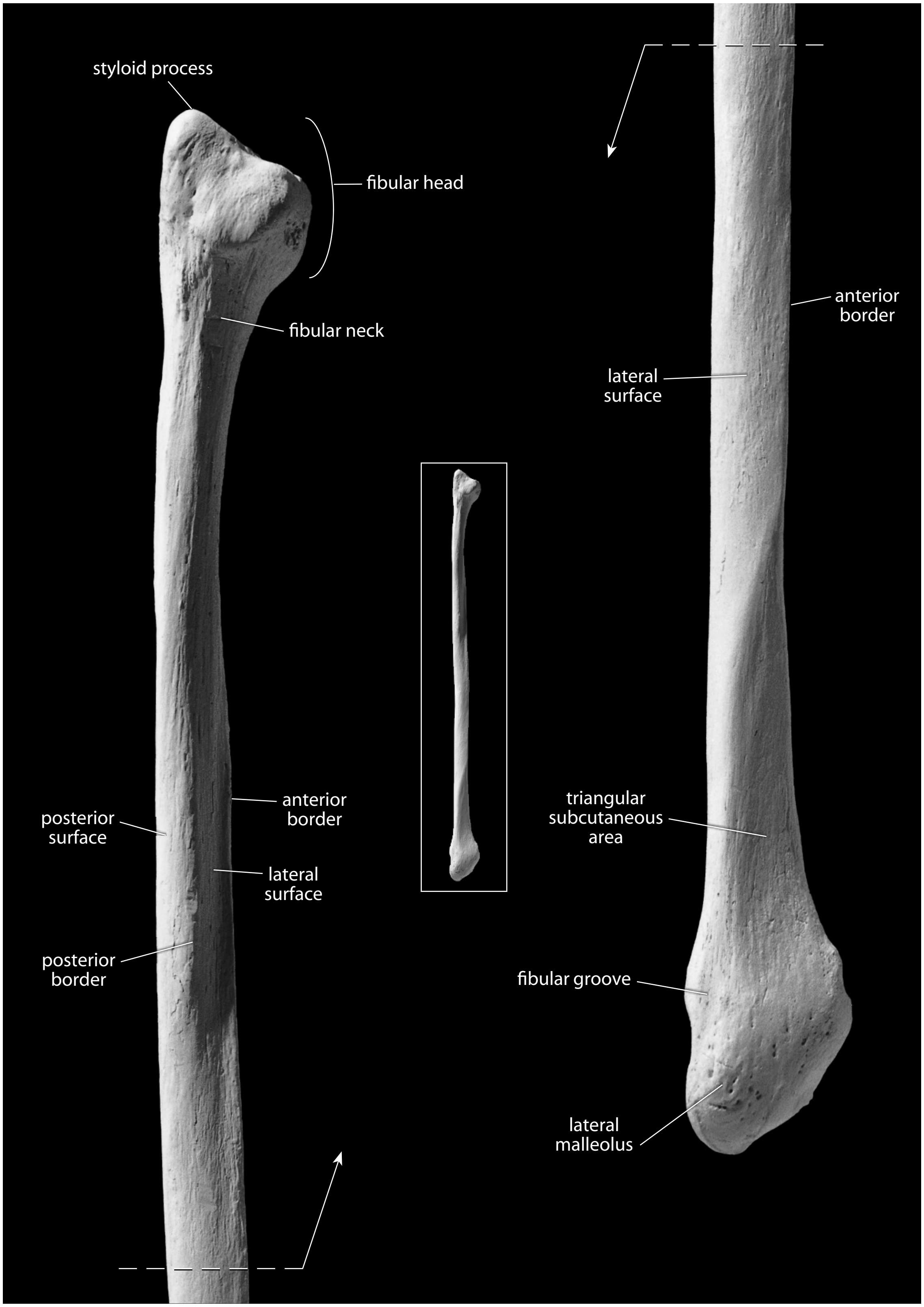

Figure 12.21 **Right fibula, lateral.** *Left:* proximal end; *right:* distal end. Natural size.

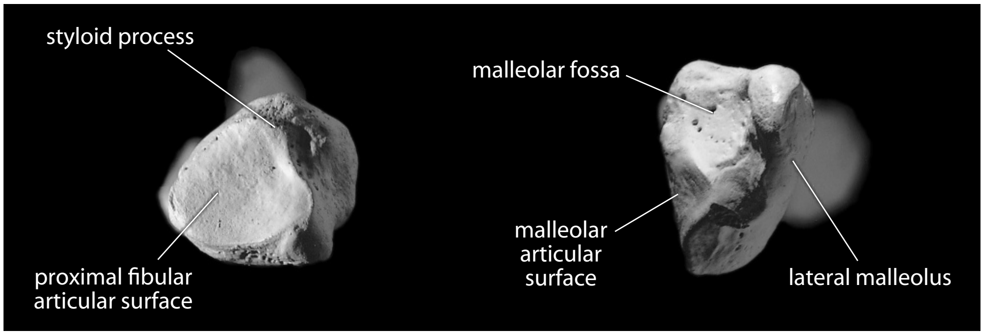

Figure 12.22 **Right fibula.** *Left:* proximal view; anterior is up; lateral is toward the right. *Right:* distal view, posterior is up; lateral is toward the right. Natural size.

i. The **posterior surface** lies between the interosseous border and the posterior border. The **medial crest**, the origin of the *tibialis posterior* and *flexor hallucis longus muscles,* is located on the posterior surface.

j. The **posteromedial border** (or **margin** or **crest)** (or **oblique line**) begins below the medial side of the fibular head, arcs laterally, then spirals medially across the posterior surface of the bone, finally merging with the interosseous border inferiorly. It marks the separation between the *tibialis posterior muscle* and the *soleus* and *flexor hallucis longus muscles.*

k. The **medial surface** is the slightly anteriorly facing surface between the anterior and interosseous borders.

l. The **interosseous border** (or **margin** or **crest**) is an elevated crest that runs down the medial surface of the shaft. Attached to it is the *interosseous membrane*, a fibrous sheet that binds the fibula and tibia and divides the lower leg musculature into anterior and posterior compartments.

m. The **surface for the *interosseous membrane*** is the broad, flat area on the medial aspect of the distalmost shaft.

n. The **nutrient foramen** opens proximally on the posteromedial surface, at about midshaft level. The cross section of the fibular shaft can be extremely variable in this region.

o. The **triangular subcutaneous area** is located distally, immediately above the lateral malleolus. The lines forming the two vertical sides of the triangle converge to become the anterior border at the apex of the triangle.

p. The **lateral malleolus** is the inferiormost (distalmost) projection of the fibula. Its lateral, nonarticular surface is subcutaneous, forming the lateral knob of the ankle.

q. The **malleolar** (or **distal**) **articular surface** is a flat, medially facing, triangular surface whose apex faces inferiorly. The surface articulates with the lateral surface of the talus.

r. The **malleolar fossa** is located just posterior to the distal articular surface. It is the attachment site of the *transverse tibiofibular* and *posterior talofibular ligaments*, which strengthen the ankle joint.

s. The **fibular groove**, for *tendons of the fibularis (peroneus) longus* and *fibularis (peroneus) brevis muscles*, marks the posterior surface of the distal fibula. These muscles plantarflex and evert the foot at the ankle, originating in the leg and inserting at the bases of the first (*longus*) and fifth (*brevis*) metatarsals.

12.4.2 Growth (Figure 12.7)

The fibula, like the tibia, ossifies from three centers: one for the shaft and one for each end. The primary center of ossification in the diaphysis appears at about 8–9 weeks (*in utero*). The secondary ossification center in the proximal epiphysis appears at 3–4 years in females, and at about 4–5 years in males. The proximal epiphysis begins to fuse with the diaphysis at 12–17 years in females, and at 15–20 years in males. The ossification center in the distal epiphysis appears at 9–22 months in both sexes. It begins to fuse to the diaphysis at 12–15 years in females, and at about 15–18 years in males (Scheuer and Black, 2000).

12.4.3 Possible Confusion

The proximal and distal fibular ends are distinctive and are rarely confused with other bones.

- The distal end is flattened along the plane of the articular facet, whereas the proximal end of the fifth metatarsal, for which a distal fibular end might be mistaken, has two facets and is flattened perpendicular to the planes of each.
- Fibular shafts are thin, straight, and usually quadrilateral (sometimes triangular), with sharp crests and corners. Thus, they are thus more irregular in cross section than either radial or ulnar shafts (see cross sections in Chapter 14).

12.4.4 Siding

- For an intact fibula, the articular surfaces for the tibia are medial, the fibular head is proximal, the flattened end is distal, and the malleolar fossa is posterior.
- For the proximal end, the styloid process is lateral, proximal, and displaced posteriorly. The articular surface faces medially and is also displaced posteriorly. The neck is roughest laterally.
- For the shaft, try to use intact specimens for comparison. The nutrient foramen opens proximally. The sharpest crest on the triangular proximal end is the interosseous border. This expands downshaft to a rough, flattened surface. The distal aspect of the shaft is marked by a line diverging from the trend of the interosseous border in the direction of the side from which the bone comes.
- For the distal end, the malleolar fossa is always posterior, and the articular facet is always medial, with its apex pointed inferiorly.

12.4.5 Fibular Measurements (Figure 12.23)

Measurements of the fibula are infrequently used for stature estimation, age estimation, and other purposes.

1. **Maximum fibular length** (Martin, 1928: 1052, #1; Buikstra and Ubelaker, 1994: 84, #75): The maximum length that can be measured between the top of the styloid process and the bottom of the lateral malleolus. Measured with an osteometric board.
2. **Maximum fibular midshaft diameter** (Martin, 1928: 1052, #2; Buikstra and Ubelaker, 1994: 84, #76): Determine the location of midshaft using 50% of maximum length. Using a sliding caliper, determine the greatest diameter of the shaft at midshaft.
3. **Fibular midshaft circumference** (Martin, 1928: 1053, #4): Determine the location of

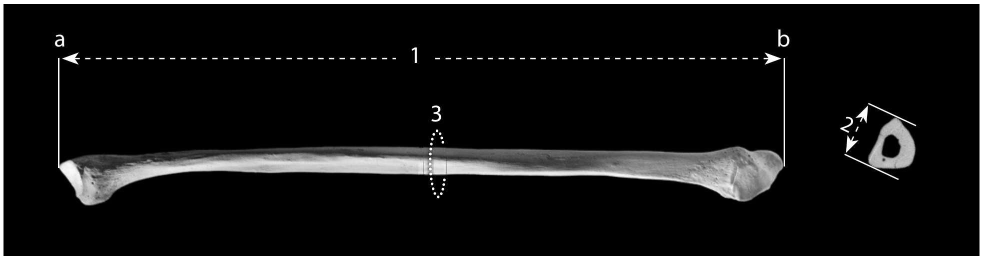

Figure 12.23 **Fibular measurements.** One-fourth (bone) and one-half (CT scan) natural size.
Locations: a) superiormost point of styloid process; b) inferiormost point of lateral malleolus.
Measurements: 1) maximum fibular length; 2) maximum fibular midshaft diameter; 3) fibular midshaft circumference.

midshaft using 50% of maximum length). Use a flexible cloth tape to determine the minimum circumference at that location.

12.4.6 Fibular Nonmetric Traits

- The cross-sectional shape of the fibular shaft is highly variable. The shaft may appear smooth or angular, and its cross section can be triangular, rectangular, or even oval.

12.5 Functional Aspects of the Knee and Ankle

The knee joint is the most complex joint in the human body, whereas the ankle joint is considerably more simple. The main actions at both the knee and ankle joints are flexion and extension. Knee extension is accomplished primarily by the quadriceps muscles. This group of muscles originates from the os coxae and proximal femur and inserts on the tuberosity of the tibia via the tendon in which the patella is embedded. Flexion at the knee is primarily accomplished by the hamstring muscles. These also originate from the os coxae and proximal femur but insert on the proximal tibia and fibula, just distal to the knee joint.

In walking and running, propulsion of the body is created by contracting muscles of the lower limb. Muscles in the anterior and posterior compartments of the lower leg (separated by the interosseous membrane) act to move the skeleton of the foot, much as forearm muscles move the hand. Plantarflexors occupy the posterior compartment, and dorsiflexors are found anterolateral to the tibia. Plantarflexor muscles, originating on the posterior side of the lower leg and attaching to the calcaneus via the Achilles tendon, contract at the same time that the quadriceps, the primary extensor of the lower leg, contracts. The coordinated action of these two muscle groups straightens the leg and plantarflexes the foot at the ankle, producing a strong ground reaction force and propelling the body forward. A comparison of the bony anatomy of the human pelvic girdle and leg with that of our closest living relatives, the African apes, reveals profound evolutionary changes related to the acquisition of bipedality more than six million years ago.